Unilateral exoskeleton assistance lowers metabolic cost in human walking

Pieter Van den Berghe, Philippe Malcolm, Samuel Galle, Dirk De Clercq
Department of Movement and Sports Science, Ghent University, Belgium
pivdnber.vandenberghe@ugent.be

1 Introduction

Exoskeletons exists for *i.a.* reducing metabolic cost, but often the ankle joint is neglected. Our ankle-foot exoskeleton reduced metabolic cost via optimal bilateral push-off timing [1]. However, push-off work was not held constant, which influences metabolic cost [2]. Unilateral exoskeleton assistance could be useful for restoring symmetry in pathologies with unilateral impairments (*e.g.* hemiplegia). As a first step towards clinical use of unilateral assistance we wanted to study the effects of unilateral assistance and asymmetry in healthy subjects.

2 Methods

13 healthy adults (♂) walked with an ankle-foot exoskeleton that can assist plantarflexion [2]. The experiment consisted of unilateral or bilateral assistance in 9 conditions of various push-off timings (35, 43, 50 stride%) and work rates (maximal, half). Unpowered walking acted as control. Conditions were randomized. Metabolic cost was determined via indirect calorimetry. Trials were compared using RM ANOVA (α=0.05).

3 Results

Figure 1 shows net metabolic cost reduction in all conditions ($p < 0.01$), with larger bilateral (-11 till -15%) than unilateral (-6 till -9%) reductions. Power variations in the bilateral trials resulted in equal energetic demands. However, low power gave the highest reduction normalized versus work rate. Dominant and non-dominant unilateral leg assistance did not differ.

4 Discussion

Results concur with previous exoskeleton experiments, although the optimal timing was earlier than the existing guideline (~43%) [1]. Heavier subjects and a larger exoskeleton maybe led to different work profiles that could have altered the optimum.

5 Conclusions

Push-off timing and mechanical work rate seem crucial elements for a more efficient gait. Leg dominance does not seem to interact with metabolic consumption through unilateral ankle support in the abled-bodied.

6 Prospects

Further data analysis includes electromyography, kinematics and gait symmetry evaluation. Latter will respectively offer insights into possible lowered muscle activation, different joint angles and potential asymmetry accompanied by a metabolic penalty.

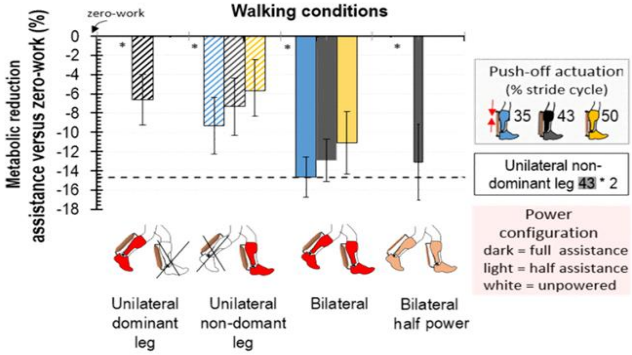

Figure 1: Net metabolic cost vs. timing-power conditions. Unilateral = striped; bilateral = full-colored bars. Values are means ± SD.

7 References

[1] P. Malcolm, W. Derave, S. Galle, and D. De Clercq, "A simple exoskeleton that assists plantarflexion can reduce the metabolic cost of human walking.," *PLoS One, 2013*

[2] S. Galle, P. Malcolm, and D. De Clercq, "2D Parameter sweep of bilateral exoskeleton actuation," *Dynamic Walking 2014*